Digital engineering in construction comprises all digital technologies and tools that are imperative for the construction project. One of the most advanced and commonly used digital technologies in the construction segment is BIM or Building Information Modelling.BIM has been able to virtually assess all the important aspects of a construction project from planning designs to planning the resources and assessing the risks of the design and cost-effectiveness. Based on these aspects, the current study aimed to analyse the implications of digital engineering and BIM in the UKs design, construction and maintenance of highway infrastructure.To address the aim of the study, a survey was conducted amongst the employees associated with various highway infrastructure projects in the UK. The study included 68 employees associated with various highway infrastructure projects in the UK. Based on the current findings, it was indicated that all the implicative factors of using BIM and the advantages of using BIM in the projects are significant as the p-value was less than 0.05. Therefore, the usage of BIM is very important in highway construction projects and overall usage. Limitations and future scope of the study have also been presented.Chapter 1: IntroductionBackgroundDigital Engineering, the targeted form of the digital transformation of engineering is emerging with different names globally, such as Industry 4.0. Digital engineering incorporates digital technologies such as IoT, smart cyber-physical systems, big data, AI, ML, robotics, virtual reality (VR), augmented reality (AR), digital twin, 3D printing, digital trust, and blockchain (Zimmerman, Gilbert, and Salvatore, 2019).Digital engineering is a manifestation of digital transformation in the field of engineering. Digital Engineering in the construction segment, or Building Information Modelling (BIM), is much more than developing models. It emphasises harnessing the true potential of the construction industry and creating a platform for multiple applications by integrating digitisation and GIS.This state-of-the-art digital technology enables the industry to integrate data about a buildings design, construction, and future function to develop the most efficient delivery methods (Zimmerman et al. 2019). In due course of time, the utility of BIM has only increased and using different modules, and the industry will be able to apply digital engineering solutions to many problems that otherwise have convoluted solutions (Smith, 2014).Construction has started to use these engineering methods to develop connected systems of sensors, intelligent machines, mobile devices, and new software applications, all integrated on a central platform of building information modelling (BIM) (Shen et al. 2010). Their adoption has only increased in the past decade enabling companies to boost productivity, manage complexity, reduce project delays and cost overruns, and enhance safety and quality.Rationale of the StudyMany incumbents in this fragmented industry have been struggling to adapt and benefit from BIM and digital technologies. A wide range of successful implementations highlights opportunities along the construction value chain (Shen et al. 2010). Digital engineering and BIM have allowed the commercial, infrastructure, and industrial sectors to showcase tremendous efficiency and productivity gains for the industry.Digitalisation has fundamentally changed the industry, enabling efficiency and quality gains along the value chain and reshuffling the competitive league table of companies and countries. The key feature of the technology transformation is the software platform and control layer, which consists in a large part of BIM.As the successor to traditional computer-aided design (CAD), BIM now serves all stakeholders along the value chain, using virtual modelling and information to simulate any aspect of the assets life (He et al. 2012). Further up the architecture, new additive construction methods, such as 3-D printing, are becoming applicable even to large-scale building components and concrete structures (Merschbrock and Munkvold, 2015).Companies can also use 3-D scanners to create digital models of complex buildings and thereby facilitate renovations, conduct quality assurance, and monitor the deterioration of materials. The application of digital technologies in specific use cases demonstrates the enormous opportunities along the value chain, from early conceptual design to the very end of an assets life cycle, in the demolition phase (He et al. 2012).By applying the right technologies in the right way, construction companies can reduce the assets construction time and whole-life-cycle cost and enhance the quality of processes and improve safety, working conditions, and sustainability. Therefore, it is important to understand how digital engineering and BIM have been applied to the highway infrastructure projects of the UK.Aims and objectivesThe research aims to analyse the implications of using digital engineering and BIM in the UKs design, construction and maintenance of highway infrastructure.The research objectives are;To analyse the present methods of designing, constructing and maintaining highwaysTo evaluate the potential of digital engineering and BIM in construction projectsTo investigate how digital engineering and BIM can be used in the UK for the design, construction and maintenance of highway infrastructureResearch QuestionsThe research questions of the study are;What are the present methods of designing, constructing and maintaining highways?What is the potential of digital engineering and BIM in construction projects?How can digital engineering and BIM be used in the UK to design, construct and maintain highway infrastructure?Research StructureThe current research structure has been segregated as introduction being chapter 1 with a brief background of the study report followed by chapter 2, the literature review. The literature review had presented an in-depth assessment of the theories and review of past literature. In chapter 3, the methodology used in collecting data and other processes has been presented, chapter 4 presented the data findings and the results. Lastly, chapter 5 is the conclusion chapter whereby the research objectives have been addressed. Orders completed by our expert writers are Formally drafted in the academic style 100% Plagiarism-free & 100% Confidential Never resold Include unlimited free revisions Completed to match exact client requirementsSamples View All Services In this chapter, theoretical aspects of digital engineering and BIM has been presented based on the findings from the past literature papers and journal as well as relevant whitepapers and e-news. The in-depth description of the need and importance of digitalisation and its impact on the construction industry have been presented.Building Information Modelling (BIM) and its Contribution to the Construction IndustryBIM or building information modelling is a form of digital engineering technology whose role is to provide with the digital form of construction and asset operations. It combinescombines technology, process improvements and digital information to radically improve client and project outcomes and asset operations (Merschbrock and Munkvold, 2015).BIM is a strategic enabler for improving decision-making for buildings and public infrastructure assets across the whole lifecycle. It applies to new build projects; crucially, BIM supports the renovation, refurbishment and maintenance of the built environment, the largest sector share.BIM offers economic, environmental and social benefits across a range of different public stakeholders (Eadie et al. 2013). Social benefits can be delivered to the public infrastructure owner by utilising BIM effectively in public planning and consultation to build support for new or updated public infrastructure, such as highway placement, water containment features or public building refurbishment.This public engagement can support public infrastructure that is well designed and aligned with the needs of the local community resulting in improved social outcomes such as better resource planning, greater use of public facilities or mapping and protection of architectural historic heritage (Merschbrock and Munkvold, 2015).BIM can support environmental benefits, such as more accurate material ordering leading to less waste to landfill and optimised simulation of energy analysis leading to lower energy demands from the built environment (Latiffi et al. 2013). BIM allows to harness the value of data by using model information and new ways of working to better support new construction techniques, scheduling, cost, quality, coordination, fabrication, sequencing and facilities management to name but a few.BIM also helps architects, engineers, and constructors visualise what is to be built in a simulated environment to identify any potential design, construction, or operational issues (Eadie et al. 2013). BIM technology provides an accurate virtual model of a building digitally constructed.When completed, the building information model contains precise geometry and relevant data needed to support the design, procurement, fabrication, and construction activities required to realise the building (Khosrowshahi and Arayici, 2012). Therefore, it may be implicated that the BIM assists in more effective and efficient infrastructure project design, construction and maintenance.Existing Construction MethodsInformation technology is one of the most important existing technologies that are used in every industry for different business operations as well as in the infrastructure and construction segment. It helps to improve the construction projects management system and better management of resources in designing infrastructures and other applications (Stark, Israel, and Whler, 2010).Information sources are very important in the project success, especially in construction projects as it helps with resource management like cost assessment, schedule management, designing of infrastructure and assessment of the designs. Some of the major areas of IT application in the construction segment are resource assessment, procurement of resources, schedule management, construction flow management, cost maintenance, and project planning (Eadie et al. 2013).One of the greatest contributions of IT in the construction industry is CAD or Computer-Aided Drafting, a widely used primary designing and infrastructure management tool. It helps in designing and assessing the designs but also helps in construction planning, organising, operation, and control. CAD has also evolved over the past few decades and has developed from designing from 2D to 3D images and now even helps in 4D imaging of the infrastructure (Stark et al. 2010).The main purpose of using CAD is to assess the durability of a structure, types of materials that will improve the structure, animation of the design, and others, enabling complete assessments and predictions for the design. Another similar technology is a 3D studio, but unlike CAD it is limited to only designing and assessing the design in the construction project.AutoCAD Architecture is another existing tool still used massively in all construction projects. They help design windows, doors, walls, and the entire building or an infrastructure roadmap (Khosrowshahi and Arayici, 2012). Similar other technologies are still being used in the construction segment even when new emerging technologies have improved the efficiencies in construction. Over the past decade, construction projects have been completed and documented in Finland, Sweden, Norway, Germany, France, Singapore and Australia, demonstrating the capability of BIM in construction. Projects are demonstrated for more sustainable products than non-BIM usage (Eadie et al. 2013).BIM tools and processes have been developed to considerably improve productivity in the industry and make it possible to manage the information generated and maintained throughout the lifecycle of buildings more efficiently. Research has shown that business and IT directors of the UKs largest contractors and consultants are fully aware of the benefits of advancements in information and communication technologies.The main barriers to implementation relate to organisational readiness to change (Dakhil, Underwood, and Alshawi, 2019). Amongst the construction companies in the UK that have adopted the BIM tool had implemented them in 3 stages; stage 1 being object-based modelling, stage 2 is model-based collaboration and stage 3 is network-based integration.In stage 1, migration from 2D to 3D and object-based modelling and documentation occurs. The BIM model is made of real architectural elements that are represented correctly in all views. The BIM model is still single-disciplinary and the deliverables are mostly CAD-like documents, existing contractual relationships and liability issues persist (Eadie et al. 2013).Stage 2 is about designing and managing a building is a highly complex process that requires smooth communication and collaboration among all project team members. This stage requires integrated data communication and data sharing between the stakeholders to support this collaborative approach.The last stage comprises transition from collaboration to integration and reflects the real underlying BIM technology (Dakhil, Underwood, and Alshawi, 2019). At this stage, project lifecycle phases dissolve substantially and players interact in real-time to generate real benefits from increasingly virtual workflows.So, BIM is seen as an efficient information management methodology within construction projects. Different BIM technologies available to date may provide different organisational capabilities; hence, stakeholders are required to assess currently available technologies on the market so that selection of suitable technology may intercept a future strategy (Eadie et al. 2015).This may incorporate further services that the organisation is willing to provide in the future. Similarly, multiple tools may be required to achieve specific outcomes in some circumstances. Due to the variety of software and tools being used many different types of file formats are involved.Given that such tools provide various features with different complexities, stakeholders should ensure forward compatibility with their goals. Quantity and quality management has been an important part of such product listings. Quantity data can also assist the appropriate site management feature, like site safety and minimising onsite storage.Costing and scheduling can provide timely project completions with maximum profits/savings (Dakhil, Underwood, and Alshawi, 2019). From a UK perspective, The National Building Specification has conducted annual BIM reports and surveys, the latest 32 NBS BIM report 2015 depicts an expanding outlook, showing that BIM adoption in the UK has gained traction, 33 increasing its adoption level from 13% in 2010 to 40% in 2012 and continuing to 50% in 2014 a substantial increase 34 in a short period of time (Eadie et al. 2015).In the UK alone, the lack of interoperability is estimated to cost 100 million a year due to waste processes of poorly structured information sharing. This suggests that since the raised awareness and utilisation of BIM in the UK, traditional methods are unable to innovate and adapt.In some projects, however, it is still essential to adopt traditional 2D CAD drawings; especially for firms that have not invested in BIM, so that they can contribute to projects and make cost estimations. This way of working can still provide a positive cost improvement overall as both approaches are being utilised. For the companies that have adopted BIM methods, 2D CAD formats are compatible with BIM and can be imported and exported to the required software (Gledson and Greenwood, 2017).The adoption of BIM has heightened since the UK government announced in 2011 that all construction projects are to be delivered utilising BIM, especially in 3D (Kumar, 2015). BIM utilisation can prove to be highly efficient as a means of providing an information-sharing environment among stakeholders and as a means of eliminating excessive printing and storing of documents. This is very positive for the design team as the data required is readily available to all involved and an overall view of the projects development is also accessible.Emerging Digital Engineering Technologies for InfrastructureDigital engineering comprises of industry 4.0 and in the construction industry, it is termed as Construction 4.0. One example of digital engineering is the application of blockchain, which provides solutions to many current problems in construction information management (Tilson, Lyytinen, and Srensen, 2010).However, it is more likely that it will be built into generic IT infrastructure on top of which construction applications are built, rather than used directly by authors of construction-related software. It can potentially make construction processes less centralised, opening the need for research in that direction.Industry 4.0 strives on the principle of creating a smart construction site, simulation and virtual storage of data allowing construction companies to arrange and evaluate data from different stages of the construction project and from end-users after completion of the construction project towards delivering a faster, more flexible construction project at a higher-quality and reduced cost (Klinc and Turk, 2019).However, despite the advantage and benefits of applying industry 4.0 concepts for construction projects, few studies have been conducted globally towards examining the awareness of construction professionals for the application of the industry 4.0 concept in the construction segment.The main idea of digital engineering is to create a digital construction site assisted by attaching internet-connected sensors like IoT on the equipment and each stage of the construction project to monitor progress coupled with drones and virtual simulation (Klinc and Turk, 2019).This opinion recognises different digital technologies as the process of implementing modern technology to encourage the digitisation of the construction industry as well as the supply chain; thereby, leading to an increased performance of the sector.Table 1: List of emerging digital engineering toolsDigital engineering technologiesAnalytics/big data, robotics RFID, human-machine collaboration, additive manufacturing, digital WMS, augmented reality in production, predictive tools and systems, Artificial Intelligence, CRM systems, cloud-based tools and technologies, social media, Machine learning, Green technologies, sustainable construction technologies(Forcael et al. 2020) This chapter of the study details the research methods, which are to be undertaken for the completion of the research regarding the implications of using digital engineering and BIM in the design, construction and maintenance of highway infrastructure in the UK.Research Paradigm and PhilosophyThe research paradigm depicts a verified and established model being used to investigate how the research problem can be addressed (Antwi and Hamza, 2015). The three types are methodological, epistemological and ontological. The research philosophy depicts the investigators ideas and thoughts regarding approaching the research to answer the research problem (Kumar, 2019).Positivism research philosophy is related to the concept of learning the truth and science to gain adequate knowledge related to the subject area. A positivism research philosophy has been used in this investigation for or procuring transfers the knowledge about the challenges of training and progress of the workforce in the construction of the UK from verifiable sources using quantitative methods and their perceptions.The research related to the challenges associated with executives in the construction sector would be conducted by gaining information from all the possible sources, which help the researcher to extract the truth about the subject with having factual details.Research DesignResearch design refers to the general planning that has demonstrated the stages for justifying the fulfilment of the research goal. The research design depicts the investigators overall plan for providing a solution to the research problem (Kumar, 2019). The exploratory research design has been used in this investigation to evaluate the perceptions of using digital engineering and BIM in the design, construction and maintenance of highway infrastructure in the UK.Moreover, the information based on the strategies and planning against the challenges are also reflected through the following exploratory research design. Following a particular research design, the researcher would also identify the working fields in the construction sector and the loopholes of service from the end of employees or management that has affected the service quality.Research ApproachResearch approach has enabled the researcher to determine the progress pattern of the study through evaluating the evidence and formulating effective decisions. Following an inductive research approach, the connection between the research components is explored.The inductive research approach would also help the researcher connect the study parameters for framing the justification and analysis against the particular research goal. The research would receive a new direction of the study by extracting quality details about the challenges in the construction sector from the secondary sources highlighted as the advantage of research. On the other hand, relying on factual details would also make contradictions related to the strategies associated with preventing the challenges. The assessment of the study would also be critical by following the approach.Research StrategyResearch design is described through the activities that need to be incorporated for completing the study and publishing adequate information against the argument. The research strategy is mainly formulated based on the study pattern and the researchers capabilities, which has also indicated the completion of research in a systematic manner (Saunders and Lewis, 2012).It involves the appropriate selection of research philosophy, approach and design, data collection method, and interpretation of collected data. The research related to the implications of using digital engineering and BIM in the construction sector would be progressed through a quantitative manner as the information of employees would be explored for extracting the details related to the issues of the employees.Data Collection MethodsThe data gathering method mainly focused on the approaches and techniques of collecting the information that will be analysed for exploring the study. The general research studies follow the primary and secondary data collection method (Saunders and Lewis, 2012).The research on the perceptions of digital engineering and BIM usage in the design, construction and maintenance of highway infrastructure in the UK has been conducted through the following survey methodology. The secondary information has been collected from the journal articles, books, website articles and reports published by different companies. Primary data will be collected from the employees of different construction companies in the UK to help the researcher interpret the subjects critical details.Sampling MethodsSampling is considered the approach applied in the statistical analysis where the predetermined observation numbers are extracted from a large population for any meaningful purpose. As the study would explore the perceptions of usage of digital engineering and BIM, purposive method from non-probability sampling has been incorporated which allowed the choice of targeting all employees from the construction industry in the UK to be chosen randomly for the survey.Initially, a total of 120 questionnaires were received from the survey and after compilation and cleaning of the data only 68 questionnaires or responses were selected based on completely filled-in responses. Therefore, the same size of the study is 68 employees from the companies that are working on highway infrastructure projects in the UK.Data AnalysisThe data analysis section will demonstrate the system of assessing and evaluating the information by utilising analytical and legal reasoning. The interpretation of collected primary and secondary data would justify the execution of the goal of the research (Kumar, 2019). The quantitative data would be analysed through descriptive analysis which would explore the critical aspects of the faced challenges of employees in the construction sector.Quantitative data gathered from the participants would be evaluated using the SPSS tool to justify the employees opinions about their perceptions of digital engineering and BIM usage. Different statistical tools have been conducted, like distribution analysis, frequency analysis, correlation, ANOVA testing and regression.Ethical ConsiderationsEthical aspects also need to be followed by the researcher to make the study reliable and validate for future recommendation. The research is based on identifying perceptions of digital engineering and BIM usage in the construction segment, especially highway infrastructure in the UK.The employees are also not asked questions requiring personal data, which is included under the ethical principles. In contrast, the employees are already informed about the questions asked in the survey. The research would also follow the legal aspects of the Data Protection Act (1998) which has ensured the maintenance of security protocol for conducting the study. The university however provided the ethical approval. In this chapter, the findings from the statistical assessments have been presented. The study conducted only statistical analyses and was segregated into the descriptive and inferential analysis. The descriptive assessments were presented in the form of frequency assessments and graphical presentations, whereas, the inferential part was presented through ANOVA, correlations, and regressions.This chapter has further five more sections, the demographic part, the general description, reliability tests, hypothesis 1 testing and hypothesis 2 testing. In addition to these sections, there is also a summary section that concludes the findings from the statistical assessments.Descriptive AssessmentBased on the current findings, it was found that the majority of the participants of the study were technicians (18%), followed by 16% for civil engineers, 10% were highway contractors, 13% were also architects.Figure 1: OccupationFurthermore, it was also found that 24% of the total participants were maintenance contractors, 19% were building contractors and civil engineering contractors, and only a few were from government authorities or local authorities involved in the targeted highway projects.Figure 2: Type of companyTo assess the systems used in order to gather and store information on projects and programs of work, it was found that 34% of them use BIM whereas 18% still use symbology and 25% use the companys own systems.Figure 3: Type of systems usedFurthermore, the level for BIM usage used in the current highway projects has been assessed and 52% of them use level 2, which comprises basic BIM applications, followed by 19% using level 3, which includes iBIM, lifecycle management, and other advanced BIMs.Figure 4: Level of BIM usageFurthermore, the level of BIM do clients ask for on highway projects and programs was also assessed and 32% believe that customers demand level 2 application of BIM whereas 26% of them say that customers demand level 3 BIM applications.Figure 5: Level of BIM demanded by clientsFurthermore, the participants of the study were also asked for their perceptions on the benefit of applying all levels of BIM on highway projects. It was noted that at least 72% of the total participants of the study indicated that there is a benefit of applying all levels of BIM on highway projects and programs. However, 9% of the participants also denied the same. This may indicate that they either have low information on the applications of BIM or have only used BUM for certain levels of construction work.Figure 6: There is a benefit of BIMIn this section, the employees were asked for the type of technology used other than BIM in the highway project and 54% of the total state that they use 3D and 4D CAD tools, followed by 24% using 3D studios for the projects and 22% used other commercial applications.Figure 7: Tools other than BIM in constructionLastly, the implications to using BIM indicated that the majority of the participants perceived them to be all relevant and they were cost-effectiveness, environmental preservation, low carbon footprint, redesigning of existing infrastructure, mapping of the highways, assessment of raw materials, predictive assessment of the durability, risk assessment and efficiency of the project workflows. No relevance was however also mentioned for cost-effectiveness and Redesigning of existing infrastructure, whereas, for others, some also stated that it was irrelevant from BIM usage.Figure 8: Advantages of using BIM In this section, the first hypothesis has been tested and interpreted using correlation tests, regression, and ANOVA tests. A correlation test was conducted to check the degree of relationship between the independent and the dependent variables because the Pearson correlation test was conducted (Gogtay and Thatte, 2017).Furthermore, the ANOVA test was done to check the degree of variance amongst the responses or independent variables and its overall impact on the dependent variables. Finally, the regression test was conducted to check the independent variables impact on the dependent variable and explore if the null hypothesis is rejected or accepted.The independent variables of the current hypothesis were It is the responsibility of the Government to ask for BIM on all highway projects and programs, The civil engineering/highways industry should take the lead in promoting BIM, BIM is solely theresponsibility of the client organisation, There is a need to raise the profile of BIM within the Civil / Highway engineering Industry, There is a need to raise the profile of BIM for the Public, Asset holding statutory authorities should introduce BIM on all Civil & highway maintenance Programs, The use of BIM systems should be mandatory for all new civil / highways infrastructure schemes.There is a slow-up take in the use of BIM on highway schemes in the UK due to the cost of the systems. From the correlation test (table), it was observed that all the independent variables of the hypothesis had a high correlation value and positive at more than 0.8 and all the variables are significant at p